High Frequency Propagation Studies in the Coastal Environment

David Farmer
Institute of Ocean Sciences
9860 West Saanich Road
Sidney, BC V8L 4B2
Phone: (250) 363-6591 Fax: (25) 363-6798 email: farmerd@dfo-mpo.gc.ca

Award #: N00014951-0765

LONG TERM GOAL

To learn how small scale physical and biological processes contribute to the scattering of high frequency acoustic signals. To understand the relationship between bubble distributions, turbulent flows and the scattered signal. To develop models of these processes.

SCIENTIFIC OBJECTIVES

To develop improved measurement approaches, to carry out high frequency propagation experiments, and to develop combined oceanographic, acoustic propagation models incorporating effects due to waves, bubbles, turbulence and marine life

APPROACH

Our approach involves development of specialized propagation apparatus for carrying out high frequency (12kHz-300kHz) propagation tests over modest ranges in coastal environments including the near surf zone. Simultaneously, measurements are acquired of the wave field, the vertical distribution of bubbles, the bubble size distribution and the turbulence. Our analytical approach involves development of a model that combines (i) a satisfactory representation of the bubble injection processes and initial bubble size distribution, (ii) a description of the subsequent evolution of bubble density and size distribution due to buoyancy and gas dissolution, (iii) a description of the spatial development of the bubble cloud under the influence of advection and turbulence, and (iv) a propagation model that incorporates both boundary effects such as surface waves and sea floor interactions and the volume scattering due to bubbles and turbulence. The work is being carried out with S Vagle (IOS) and through collaborations with G Deane (SIO), J Preisig (WHOI) and C Garrett (UVic). Studies of biological scatter are being carried out in collaboration with Z Ye (Taiwan) and M Trevorrow (IOS).

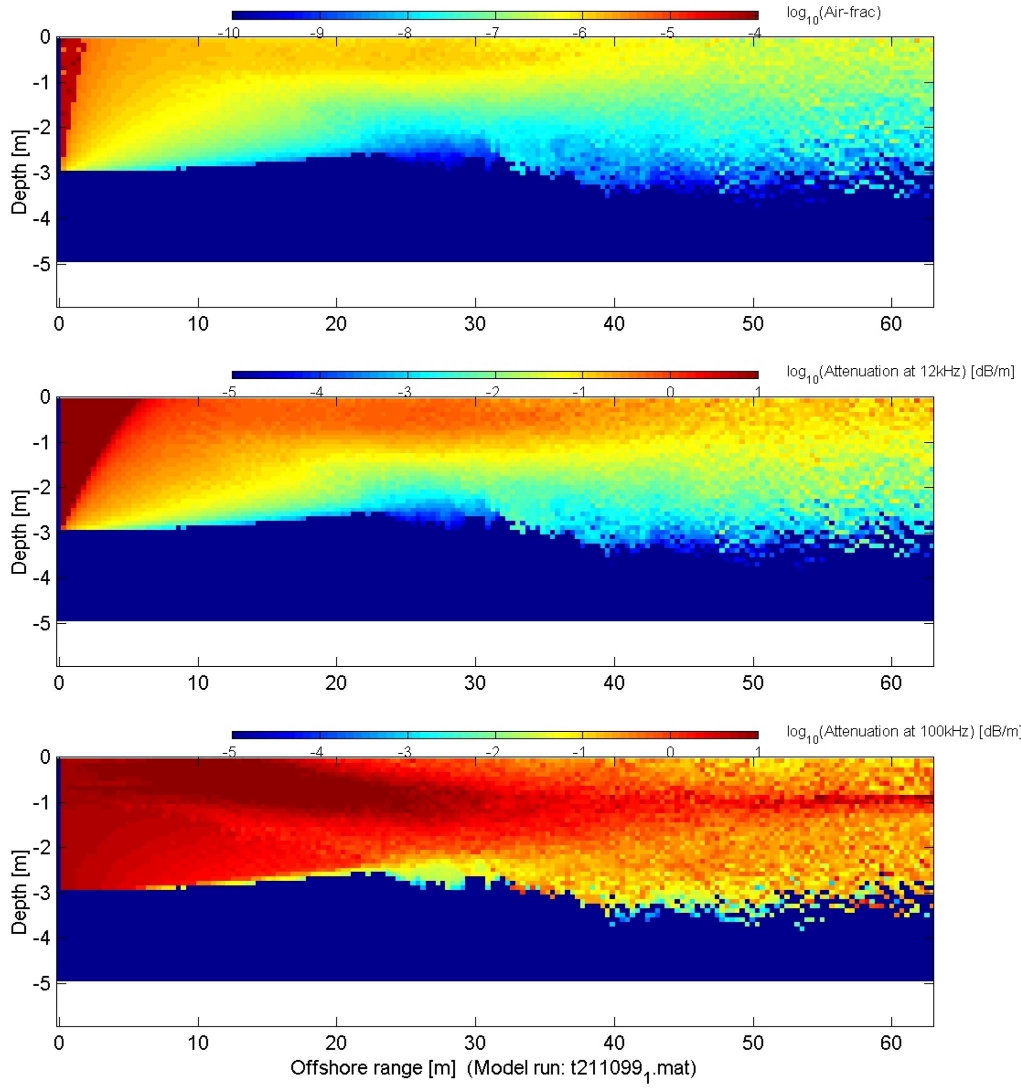
Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1999**	2. REPORT TYPE	3. DATES COVERED **00-00-1999 to 00-00-1999**
4. TITLE AND SUBTITLE **High Frequency Propagation Studies in the Coastal Environment**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Institute of Ocean Sciences,9860 West Saanich Road,Sidney, BC V8L 4B2 ,**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

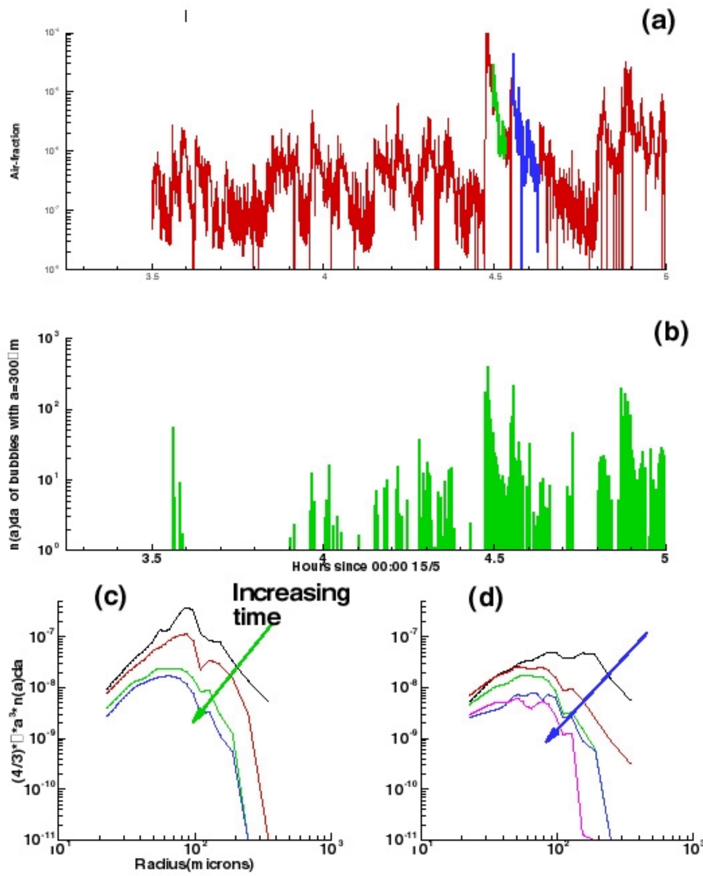
Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18



1: Model calculations of the evolution of a bubble field in the surf zone. (Top) Bubbles injected at left by breaking waves, move offshore under the combined influence of advection in a rip current and turbulent diffusion, where the turbulence is generated by wave interaction with the sea floor. (Middle) Calculated attenuation by the bubbles at 12kHz. (Bottom) Calculated attenuation at 100kHz.

WORK COMPLETED

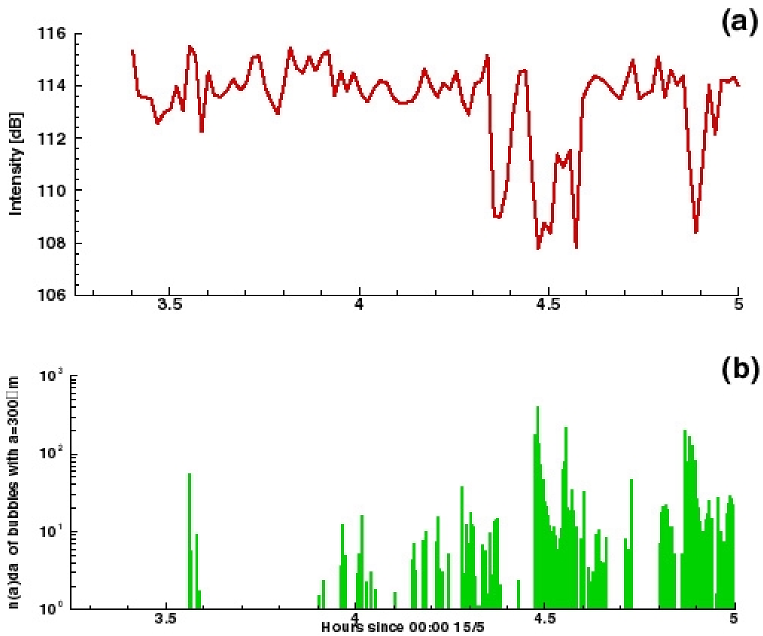
Work was completed on (i) a model to explain bubble size distributions generated by breaking waves (Garret, Li & Farmer, 1999), and (ii) a model to describe effects of bubble cloud evolution in the surf zone and consequent influence on high frequency propagation, under the influence of the combined effects of injection, rip currents, turbulence, gas dissolution and buoyancy (Vagle, Deane & Farmer, 1999); (iii) an experiment was conducted in which simultaneous back scatter and forward scatter measurements were acquired in the surf zone at frequencies of 12kHz and 100kHz (Vagle & Farmer, 1999); (iv) coherent Doppler measurements have been acquired of turbulence beneath breaking waves, simultaneously with bubble distributions; (v) an instrument has been developed for simultaneous back and forward scatter measurements beneath breaking waves in the open ocean and preliminary data have been acquired with it, and (vi) analysis has been completed of 12kHz scatter from fish in a sound channel, demonstrating identification of individual salmon at ranges of 7km (Farmer, Trevorrow & Pedersen, 1999).



2: (a) Time series measurements of air fraction measured in the surf. A large double peak occurs due to enhanced breaking. (b) Concentration of bubbles of radius 300microns, resonant at a frequency of 12 kHz corresponding to our propagation path. (c,d) Bubble size evolution following wave breaking. The two sets of curves correspond to the periods shown as green and blue respectively in (a).

RESULTS

Bubble size distributions at source, knowledge of which is crucial to the understanding of bubble effects on high frequency propagation, have been described with measurements and explained in terms of the link between turbulence and bubble break-up. A dimensional analysis that takes account of the competition between turbulent pressure fluctuations and surface tension, leads to a -10/3 bubble radius power law distribution. But this does not account for the observed number of very small bubbles that would seem to imply very high turbulence intensities. Our model invokes turbulence intermittency to explain the observations. Effects of buoyancy and dissolution in shaping the bubble size distribution have been incorporated in a two-dimensional advection diffusion model to account for effects of near surface turbulence and advection by Langmuir circulation. These results provide a basis for calculating near surface scattering and attenuation and demonstrate that these effects reach a maximum at a frequency of approximately 30kHz.



3: Measured attenuation of a 12kHz signal propagating from the surf zone to the end of the pier. Large signal drop-outs occur simultaneously with the injection and persistence of 300micron bubbles resonant at the propagation frequency.

These results have been applied to acoustic propagation in the surf zone. Specifically a coupled hydrodynamic-acoustic model has been implemented in which bubbles are injected in the surf and advected offshore (Figure 1). As the bubble cloud moves offshore it is vertically redistributed by bottom boundary layer turbulence, while also subject to buoyancy sorting and gas dissolution. From the modeled bubble distribution, attenuation of high frequency propagation is calculated. The results are compared with direct observation of measurements acquired in the surf zone near the Scripps pier. Figure 2 shows air-fraction as function of time, together with the concentration of bubbles of radius 300µm, which are resonant at 12kHz. The figure also shows the rapid evolution of bubble size distribution after breaking. Specifically the 300µm population decays rapidly after injection due to buoyancy sorting. Figure 3 shows the effect of the 300µm bubble population on the attenuation of the 12kHz signal propagating between the surf zone and the end of the pier. Dropouts lasting several minutes are associated with high bubble concentration.

IMPACT/APPLICATION

Attenuation and scattering effects of bubbles and turbulence have direct application to high frequency systems used in synthetic aperture sonars and in acoustic communications. Models of these effects are required to understand the performance of such systems in inshore environments and in optimising frequency selection, signal design and related characteristics.

TRANSITIONS

The work carried out under this project has been incorporated in the ONR supported Acoustic Communications study (Dr T Swean) in conjunction with J Presig, G Deane and K Commander.

REFERENCES

Farmer, D.M, Vagle, S., & M. Li, 1999, "Wave breaking, turbulence and bubble distributions in the ocean surface layer", The Wind-Driven Air-Sea Interface Electromagnetic and Acoustic Sensing, Wave Dynamics and Turbulent Fluxes, Sydney, Australia, 11-15 Jan 1999 , Edited by Michael L. Banner,The University of New South Wales, Sydney, Australia, ISBN 0 7334 0586 X

Garrett, C., M Li & D. Farmer, 1999, A note on the connection between bubble size spectra and energy dissipation rates in the upper ocean. In press: ***J. Phys. Oceanogr.***

Vagle, S., Farmer, D., & G. Deane, 1999, Bubble Transport in Rip Currents, submitted: *J. Geophys. Res.*

Vagle S, & D. Farmer, 1999, Near Shore Acoustical Network Experiment (NSANE): Measurements of Environmental Parameters and High Frequency Propagation, Institute of Ocean Sciences, Report.

Farmer, D., Trevorrow, M.V., & B. Pedersen, 1999, Intermediate range fish detection with a 12kHz sidescan sonar, *J. Acoust. Soc. Amer.* 106 (5)